IRON ORE COMPANY OF CANADA

PROJECT 2616

EVALUATION OF VARIOUS ORGANIC BINDERS IN PELLETIZING OF CAROL CONCENTRATE

BY

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FINAL REPORT
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CENTRE DE RECHERCHES MINERALES

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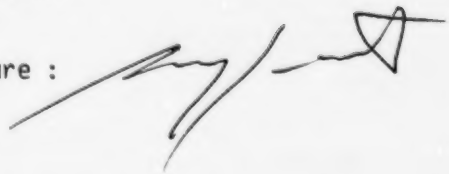
Signature : 

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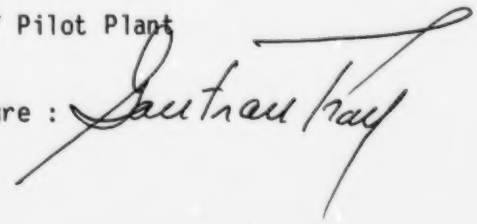
Signature : 

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SUMMARY

This report describes the results of a second study on the performance of various organic binders in iron ore pelletizing.

The organic binders investigated are a liquid aniomic polymer named Alchem 8C26, 4 different CMC's (carboxymethylcellulose) and peat moss.

The performance of the binders during balling and firing is evaluated and the green ball and fired pellet properties are compared to those obtained with bentonite addition. The effect of flux addition is also discussed.

Among all the organic binders tested, the sample of CMC Peridur C-10 showed the best behaviour. The fired pellet physical properties obtained with this binder are similar to those of bentonite pellets while the reducibility index is significantly higher.

Some recommendations are made for more research work to optimize the Peridur and flux addition rates and for a plant trial.

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1. INTRODUCTION

The agglomeration process has been developed for the purpose of improving the blast furnace performance. Since early commercialization of the process, bentonite was the most cost effective binder used by the pellet producers. Its good binding properties help in controlling the balling process and provide sufficient wet and dry ball strength for handling through the drying, preheating and firing process.

However the use of bentonite contaminates the fired pellets by increasing the silica content which translates in higher ore concentration costs. The processing of crude bentonite also requires a drying and grinding plant along with an extensive dust collection system.

The market trends for lower pellet silica specifications have increased the interest for pellet producers to replace bentonite by an organic, volatile, binder.

The research work was undertaken in 1986. The first phase of the project consisted in a preliminary evaluation of several potential organic binders in a laboratory balling tire. The product tested included bentonite, peat moss (with and without NaOH addition), procell (wood processing by-product), some high molecular weight polymers, a carboxymethylcellule (CMC) and some lignosulfonates.

The best results were obtained with a high molecular weight polymer named 8C26 and with peat moss. These products were selected for pilot scale tests. The CMC called Peridur also showed an interesting behaviour and was recommended for further testing.

The fired pellets produced with the 8C26 and peat moss were comparable to bentonite pellets except for their lower abrasion resistance. The addition of fluxes partly solved that problem.

In conclusion of this first study it was decided to continue the research work to optimize the pelletizing conditions with peat moss and the 8C26. The program of this second phase also included a more detailed evaluaton of CMC's (Peridur and others).

The results and conclusions of this work are presented in this report.

2. CONCLUSIONS

The batch tests in the balling tire showed that the sample of CMC Peridur C-10 was the best organic binder among those evaluated. The results were confirmed at a pilot scale where the green ball quality obtained was equivalent to the standards established for regular bentonite pellets. The quality of the green ball made with 0.1% Peridur C-10 was not improved by the addition of sodium carbonate.

The balling tire tests with the polymer 8C26 showed a very high green ball plasticity (drop number) but a relatively low dry strength. The green balls made with peat moss and NaOH were also weaker. Some tests made with a combination of either 8C26 or peat moss with bentonite resulted in better green ball quality.

The fired pellets made with 0,1% Peridur C-10 and 1.5% coke equivalent (1.0% coke breeze + 26% magnetite) showed a tumble index of 96.3% and a compressive strength of 323 kg/pellet. These excellent results were further improved by the addition of 1.0% limestone (96.6% Tumble and 347 kg/pellet).

The addition of up to 1.5% dolomite had no significant effect on the fired pellet physical properties and reducibility index as compared to Peridur pellets with no flux addition. The LTD test result was slightly deteriorated but still remains within acceptable limits.

In one of the tests, the addition rate of Peridur C-10 was lowered to 0.075%. An increase of 6% in the firing time was necessary to promote particule bonding and achieve the desired pellet strength. Part of this loss in production rate was due to the lower bed permeability.

The production of fluxed pellets (CaO/SiO_2 = 0.9 and 1.85% MgO) with 0.1% Peridur C-10 and 1.5% coke equivalent also resulted in excellent pellet quality (96.1% Tumble and 293 kg/pellet).

A significant increase of about 0.15% O_2/min in the reducibility index of Peridur pellets was observed as compared with bentonite pellets. The Low Temperature Desintegration (LTD) index was above the excellent value of 95% for both acid and fluxed Peridur pellets.

The swelling of Peridur pellets was high at 26.1% as compared to 17.7% for bentonite pellets. However, the addition of a small quantity of dolomite or limestone decreased the swelling to a nearly acceptable level (21%). The value obtained for fluxed pellets was 18.0%. The cause of the higher swelling of Peridur acid pellets still has to be determined but is believed to be due to the greater alignment of the grains during reduction because of the lower quantity of impurities in the fired pellets.

The softening test results obtained with acid and fluxed pellets made with Peridur were equivalent to the values reached with bentonite pellets.

As a general conclusion, it can be said that the properties of the fired pellets produced with the organic binder Peridur C-10 are equivalent or superior to those of bentonite pellets. A plant trial is recommended to confirm this conclusion.

The fired pellets produced with 0.1% of polymer 8C26 showed a poor tumble index. This was partly due to the high pellet porosity resulting from the excessive green ball moisture (9.8%). In order to improve the tumble index it was decided to lower the 8C26 addition rate to 0,075% (to decrease the green ball moisture and fired pellet porosity) and to add 1.5% dolomite to improve bonding. The tumble index improved from 93.3 to 95.0 and the strength from 265 to 307 kg/pellet as a result of the decrease in green ball moisture (8.8%).

The test with peat moss resulted in a low green ball drop number and a poor tumble index as compared to Peridur C-10.

At this stage we believe the 8C26 and the peat moss should only be considered on a basis of partial substitution for bentonite.

Finally, the excellent results obtained during this project leave us very optimistic about the substitution of bentonite with an organic binder in a near future.

3. RECOMMENDATIONS

The following recommendations are made for further research work in order to optimize the quality of green balls and fired pellets produced with an organic binder.

- Evaluation of different addition rates of Peridur C-10 (0.075% to 0.125%) to evaluate the effect on bed permeability, production rate and pellet quality.

- Optimisation of flux addition for acid pellets (0 to 2.5% of dolomite or limestone) in order to insure a good pellet strength and to minimize the sweeling index.

- Optimisation of the chemical composition and quality of fluxed pellets made with the organic binder Peridur C-10.

- Evaluation of the effect of a combination of bentonite with the polymer 8C26. The bentonite should provide a good pellet strength while the benefits of the organic binder would still be present. Another advantage of the 8C26 is that a higher filter cake moisture can be allowed.

- Full scale testing in one of the pelletizing unit of the pellet plant to confirm the conclusions of the pilot scale tests. A final test program could be elaborated from the recommendations of this study and from the conclusions of the plant trial.

4. PHASE I: LABORATORY SCALE

4.1 Water absorption capacity measurements

The first part of the project was done at a laboratory scale. The objective was to do a first selection amoung the 6 organic binders to be evaluated.

The products were first tested for their water absorption capacities. The ASTM plate test developed for bentonite was used with an appropriate adjustment in the weight of the samples because of their lower specific gravity . The results are presented in table I. Because this test was developed specifically for bentonite the data of Table I must only be considered on a comparative basis.

The results show that the 4 CMC's and specially the Peridur C-10, have a very high water retention capacity.

The peat moss showed a value about half that of bentonite but the test is very much sensitive to the initial peat moss moisture content. The peat tested in table I was at 70% H_2O which is considered to be an ideal level for pelletizing.

No data could be obtained from the Alchem 8C26 since part of the gel formed with water went through the filter paper.

Table I

Water absorption capacity of various binders
(Plate tests)

Binder	Test Weight (g)	Water Absorption (%)
Bentonite (IOC) received 87-09-15	2.0	637
Peridur C-10	0.4	1878
Peridur XC-10	0.4	1112
Carbobind 135	0.4	1654
Tacbind	0.4	1569
Peat moss (70% H_2O)	1.0	374
Polymer 8C26	Partly soluble	-

4.2 Balling tire tests

The table II summarizes the results of all the balling tire tests. The procedure used has been described in a previous report.

The reference test with 0.8% bentonite (test #1) was done 3 times and resulted in the expected good green ball quality.

4.2.1 Tests with CMC's

A total of 4 different CMC's supplied by IOCC were tested at different addition rates. These products are the Peridur C-10 and Peridur XC-10 (both around 0.75$/kg), the Tacbind (~ 1.50$/kg) and the Carbobind 135.

The results are shown in tests #2 to #10 of table II. It appears clearly that the Peridur C-10 is superior to the other CMC's. Its cost is also the lowest and the product was then selected for pilot scale tests. The figure 1 shows the green ball quality obtained at different addition rates of Peridur C-10.

The objectives of tests #11 to 15 was to evaluate the effect of sodium carbonate and water hardness on the performance of the Peridur C-10. The tests #11 and 12 were done with regular filter cake, containing the industrial plant water, at 2 different levels of Na_2CO_3. No significant difference was observed in the green ball properties. The washing of the filter cake in deionized and the addition of Na_2CO_3 did not have more impact.

The test #25 shows that leaving the Peridur C-10 in the filter cake 4 hours prior to balling does not improve its performance. In fact the ball dry strength decreased slightly.

Table II

Balling tire tests

Test #	Binder	Mix %H_2O	Green Balls % H_2O	Drops	Wet kg	Dry kg
1	No binder	8.5	7.2	1	1.2	0.4
2	Bentonite 0,8%(*)	8.5	8.7	16	1.6	7.1
3	Peridur C-10 0.100%	8.4	8.7	14	1.5	6.3
4	Peridur C-10 0.075%	9.0	8.3	9	1.6	4.1
5	Peridur C-10 0.050%	8.7	8.5	4	1.4	2.7
6	Peridur XC-10 0.100%	8.7	8.6	6	1.5	3.1
7	Peridur XC-10 0.075%	8.8	8.4	5	1.2	2.8
8	TACBIND 0.100%	8.8	8.2	7	1.6	5.1
9	TACBIND 0.075%	8.6	8.2	5	1.5	3.9
10	Carbobind 135 0.100%	8.6	9.0	6	1.3	3.0
11	Carbobind 135 0.075%	8.4	8.4	3	1.4	2.6
	Peridur C-10 0.1%					
3	+ Na_2CO_3 0.000%	8.4	8.7	14	1.5	6.3
12	+ Na_2CO_3 0.025%	8.6	8.5	11	1.5	5.4
13	+ Na_2CO_3 0.050%	8.5	8.6	13	1.6	5.9
14	Wash + Na_2CO_3 0.000%	8.5	8.7	9	1.5	6.3
15	Wash + Na_2CO_3 0.025%	8.4	8.7	14	1.5	6.6
16	Wash + Na_2CO_3 0.050%	8.5	8.5	10	1.5	6.5
17	Alchem 8C26 0.100%	8.7	9.5	23	1.3	3.2
18	0.075%	8.8	9.7	18	1.3	2.1
19	0.050%	9.0	8.8	11	1.3	1.1
20	0.040%	8.4	8.7	7	1.2	0.6
	0.05% Alchem 8C26					
19	+ Bentonite 0.0%	9.0	8.8	11	1.3	1.1
21	+ Bentonite 0.2%	8.6	9.8	15	1.3	2.3
22	+ Bentonite 0.4%	8.8	9.7	24	1.3	5.0
	Peat moss (70% H_2O)					
23	0.75% (Dry)+NaOH 0.0%	9.8	12.0	9	0.7	0.5
24	0.75% (Dry)+NaOH 0.1%	10.2	12.8	12	0.7	1.7
25	0.50% (Dry)+NaOH 0.1%	9.3	10.4	6	0.7	3.4
3	Peridur C-10 0.1%	8.4	8.7	14	1.5	6.3
26	After 4 hours aging	8.5	8.4	13	1.6	4.4
5	Peridur C-10 0.05%	8.7	8.5	4	1.4	2.7
27	a) +0.05% Alchem 8C26	8.8	8.4	19	1.4	3.7
28	b) +0.20% Bentonite	8.7	8.4	6	1.5	3.3
29	c) +0.25% Peat moss	9.2	9.2	7	1.3	1.9
30	d) +0.25% Peat+0.1%NaOH	9.0	9.4	7	1.2	4.3
	0.4% Bent. + 0.25% Peat					
31	without NaOH	9.2	8.9	5	1.3	3.7
32	with 0.1% NaOH	9.3	9.0	9	1.4	6.2

* average of 3 tests

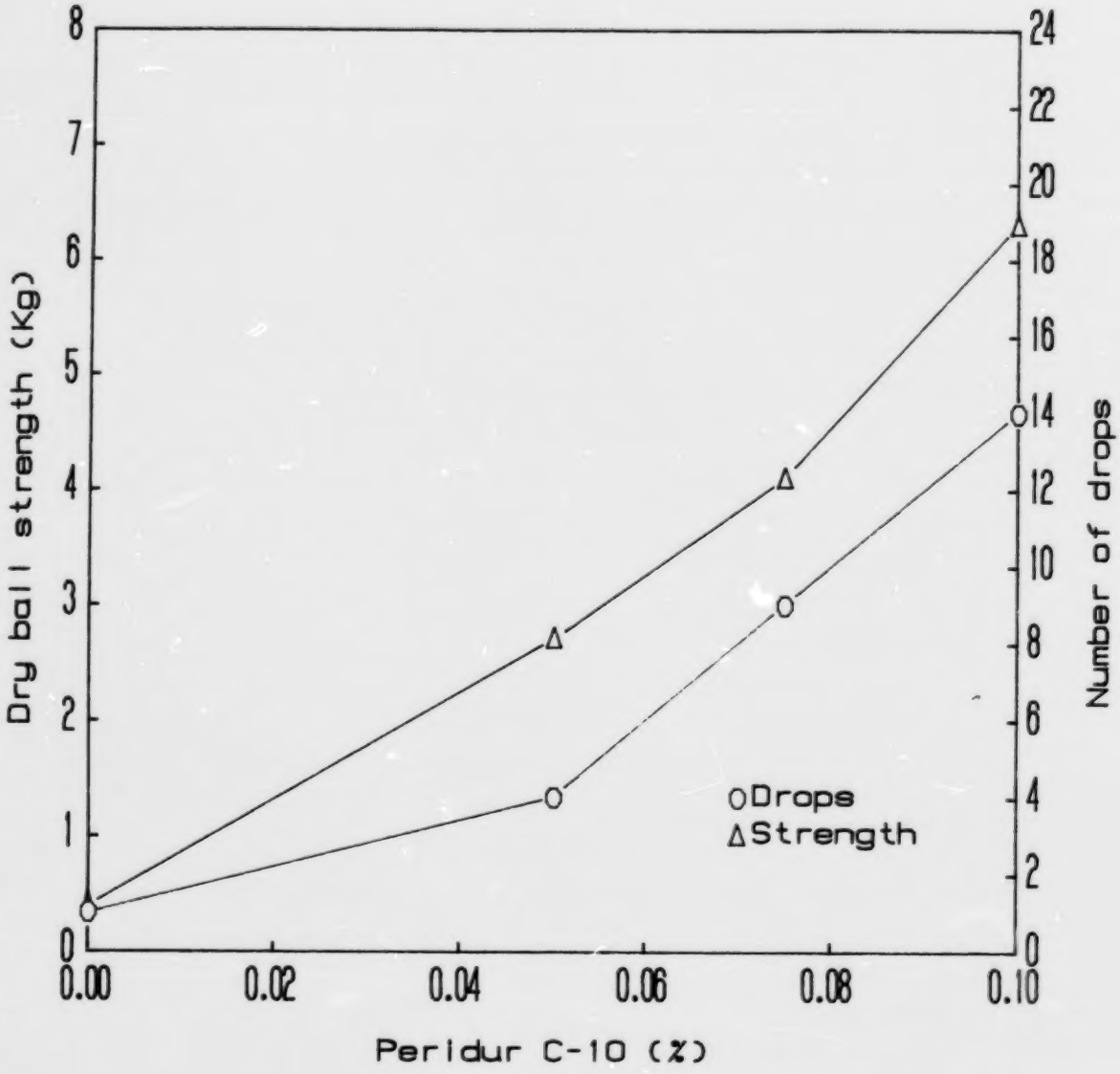

Figure 1: Green ball quality Vs % Peridur C-10

4.2.2 Alchem 8C26 and peat moss

The tests #16 to 19 were done at different levels of 8C26 (1.40 $/kg). Even at a very low addition rate the green balls were plastic and had a good drop number as shown on figure 2. The dry strength was significantly lower than bentonite green balls. Because of its good behaviour the 8C26 was selected for pilot tests.

The peat moss also showed some interesting results (tests #22, 23 and 24). The green ball wet and dry strength were low but the drop number was acceptable at very high moisture level. The addition of NaOH resulted in a significant increase in the dry strength. The peat moss also has the advantage of releasing energy during firing. It was decided to continue the testing at a pilot scale.

4.2.3 Combination of binders

Different combinations of binders were evaluated in tests #20, 21 and 26 to 31.

The mixing of bentonite and 8C26 gave some interesting results. The 8C26 increases the drop number while the bentonite improves the dry strength. The optimum mix proportion still has to be determined.

The mixing of Peridur with 8C26, bentonite or peat moss did not show any exceptionnal results. In all the cases the green ball quality obtained with Peridur C-10 alone was better.

The mixing of bentonite and peat moss resulted in very good green balls when NaOH was added. This combination could be of interest in future work.

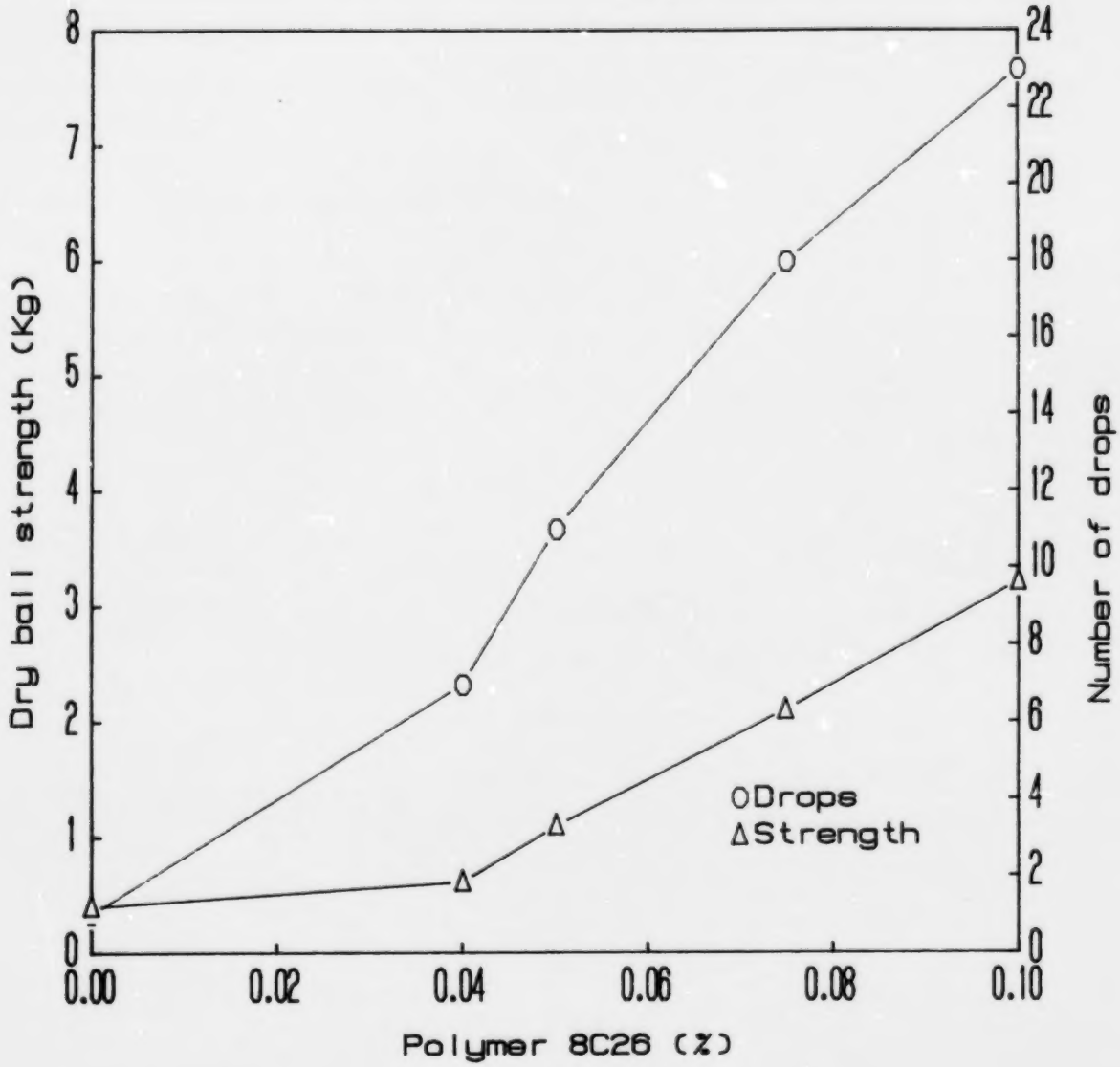

Figure 2: Green ball quality Vs % Polymer 8C26

5. PHASE II: PILOT SCALE TESTWORK

5.1 Experimental procedures

The procedures for balling in the one meter diameter disk and for firing in the 38 cm I.D. pot grate were described in a previous report.

The filter cake as received contained 1.0 to 1.1% coke and around 26% magnetite. The total energy content was about 396,000 BTU/ton or 418,000 kj/ton (coke at 27,400 kj/kg and magnetite at 500 kj/kg). We have also received some ball mill discharge (free of coke) which was filtered to 8% H_2O using a drum filter. Some chemical analysis were done on spot samples and the filter cake was considered to be representative of the normal production.

The ground bentonite was supplied by IOCC and the dolomite and limestone by the CRM. The peat moss used was representative of what is found on the north shore of Quebec and was supplied by Mr. Dave Miller. The calorific value of dry peat was analysed and showed 7,450 BTU/lb (17,330 kj/kg) as compared to 1010 BTU/lb (2 350 kj/kg) for wet peat (see appendix 1). The value for wet peat is used for the overall energy balance while that for dry peat is used for the calculation of internal heat released during firing. The peat moss was conditioned by forcing it through a 4 mesh screen and its moisture content was lowered from 88 to 70%.

The Table III shows the chemical analysis of the filter cake used for each mix. The lower % Carbon appearing for B-7 comes from the fact hat some ball mill discharge (0% coke) was mixed with the filter cake to compensate for the heat generated by peat moss. No analysis were done for B-5 because of the poor results obtained in this test.

Table III

Chemical analysis of the filter cakes

Test #	Fe	Fe_3O_4*	% C	SiO_2	Al_2O_3	CaO	MgO
B-1	65.5	28.0	0.85	4.77	0.15	0.63	0.32
B-2	64.9	26.7	0.85	4.49	0.15	0.56	0.36
B-3	64.8	25.1	0.79	4.92	0.15	0.59	0.33
B-4	66.4	25.7	0.80	4.92	0.17	0.55	0.32
B-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B-6	64.8	26.5	0.81	4.32	0.15	0.55	0.32
B-7	66.0	24.9	0.50	4.79	0.11	0.69	0.36
B-8	65.2	26.3	0.72	4.92	0.09	0.52	0.32
B-9	64.9	26.3	0.73	4.92	0.21	0.62	0.36
B-10	64.4	29.7	0.77	5.31	0.13	0.56	0.43
B-11	64.7	31.4	0.83	5.56	0.17	0.63	0.43

* Based on the analysis of Fe^{++}

Table IV summarizes the analysis of the different additives. The values are typical of plant practice.

Table V shows the size distribution of the filter cake used in each mix. Again, the values are representative of the regular production.

Table VI summarizes the composition of all the mixes. The calculation of flux additon in test #B-6 is described in appendix 2. All the binders, including the Alchem 8C26, were mixed with the filter cake in a tumbling mixer prior to balling. It all the cases the mixing was easy and resulted in uniform distribution of the binder in the material. This is a big improvement in the case of the Alchem 8C26 which was causing problems at the mixing stage in previous work. The new 8C26 used in this project had a lower viscosity and could be distributed very well in the filter cake.

Table IV

Chemical analysis of the raw materials

Additive	Fe_2O_3	SiO_2	CaO	MgO	Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O	LOI
Bentonite	3.98	53.80	2.15	2.81	17.30	0.73	0.24	0.15	2.40	1.70	13.1
Dolomite	0.38	1.89	30.20	20.90	0.58	0.02	<0.01	<0,01	0.10	0.08	46.0
Limestone	0.20	0.98	52.90	1.21	0.36	<0.01	<0.01	0.02	0.10	0.03	43.9

	% - 200 M	% -325 M	
Bentonite	N/A	N/A	(Ground at IOC)
Dolomite	74.1	51.3	
Limestone	73.7	N/A	

Peat moss: 70% H_2O
100% - 4 M
17,330 kj/kg (7 450 BTU/lb) for dry peat

Table V

Size distribution of the filter cakes

Test #	% - 100 M	% - 200 M	% -325 M	% -10 microns
B-1	96.9	82.6	63.0	25.9
B-2	96.8	83.3	64.3	24.4
B-3	97.0	82.7	62.9	24.6
B-4	97.2	82.4	62.5	23.5
B-5	N/A	N/A	N/A	N/A
B-6	97.1	83.0	66.2	23.8
B-7	97.0	82.2	N/A	26.0
B-8	96.7	82.4	66.4	26.9
B-9	97.4	86.9	66.4	22.2
B-10	97.3	83.6	64.2	23.6
B-11	97.1	83.3	64.1	21.1

Table VI

Compositions of the different mixes

Test #	Binder	Dolomite (%)	Limestone (%)
B-1	0.8% Bentonite	-	-
B-2	0.1% Peridur C-10	1.5	-
B-3	0.1% Peridur C-10	-	1.0
B-4	0.1% Peridur C-10	-	-
B-5	0.1% 8C26	-	-
B-6	0.1% Peridur C-10	7.5	3.5
B-7*	0.5% Peat (dry basis) +0.1% NaOH	-	-
B-8	0.075% 8C26	1.5	-
B-9	0.075% Peridur C-10	1.5	-
B-10	0.1% Peridur C-10	1.0	-
B-11	0.1% Peridur C-10	0.5	-

* In test B-7 the coke rate was adjusted to account for the energy generated by the combustion of peat moss.

5.2 Results and discussion

5.2.1 Green ball properties

Table VII summarizes the green ball properties for each test. Test# P-1A was rejected due to some problems in temperature control during firing.

In each test the filter cake moisture was adjusted to 9.0%. Some of that moisture was lost during mixing and balling except for test #5, with 0.1% 8C26, where a significant amount of water was added at the balling disk. The green ball % H_2O was kept at the maximum level allowed on our discharge screen. The number of drops is lower than those obtained in the balling tire tests. We believe the green ball moisture and drop number could be slightly increased in full scale operation.

The green ball strength obtained with the different binders confirmed the results of the balling tire tests. Considering the wet and dry properties, the Peridur C-10 appears to be the best organic binder.

Table VII

Green ball properties

Description	Test #	H_2O		Green Ball properties		
		Mix	Green balls	Drops	Wet Kg	Dry kg
0.8% Bentonite	P-1B	8.5	8.0	8	1.7	7.7
	P-1C	8.5	7.8	8	1.8	8.7
0.1% Peridur C-10 1.5% Dolomite	P-2A	8.5	8.3	6	1.7	5.2
	P-2B	8.5	8.3	6	1.7	5.5
0.1% Peridur C-10 1.0% Limestone	P-3A	8.7	8.3	7	1.5	5.0
	P-3B	8.7	8.5	7	1.7	5.2
	P-3C	8.7	8.3	7	1.7	5.4
0.1% Peridur C-10	P-4A	8.6	7.9	6	1.6	4.6
	P-4B	8.6	8.0	8	1.8	4.4
0.1% 8C26	P-5A	8.6	9.8	13	1.3	3.2
0.1% Peridur C-10 7.5% Dolomite 3.5% Limestone	P-6A	8.8	8.5	6	1.6	4.8
	P-6B	8.8	8.5	7	1.7	4.6
0.5% Peat (dry) 0.1% NaOH	P-7A	9.0	9.0	3	1.2	3.2
0.075% 8C26 1.5% Dolomite	P-8A	N/A	8.8	10	1.4	1.6
0.075% Peridur C-10 1.5% Dolomite	P-9A	8.6	8.4	5	1.5	3.9
	P-9B	8.6	8.5	6	1.7	3.9
0.1% Peridur C-10 1.0% Dolomite	P-10A	N/A	8.8	6	1.5	4.6
	P-10B	N/A	8.5	8	1.9	5.5
0.1% Periduc C-10 0.5% Dolomite	P-11A	8.6	8.4	7	1.5	4.9
	P-11B	8.6	8.8	8	1.7	4.4

5.2.2 Firing conditions

The firing profiles applied for each test are described in table VIII. These conditions are based on the full scale operation. When necessary, the changes in firing conditions were discussed with a representative of IOCC.

The first test, P-1A, was rejected because of some problems with the T° control. This firing cycle, which was recommended by IOCC, was repeated in test P-1B. The pellets were slightly overfired and it was decided to decrease the pressure drop and to increase the bed height (test #P-1C). These adjustments led to acceptable pellet firing.

In test P-2A the T° profile was modified to account for the small addition of dolomite. For comparison purposes, test #P-2B was run using the reference cycle P-1C.

Test P-3A (1% limestone) was done with the same cycle as P-2A. The pellets were slightly underfired because of a lower bed permeability probably due to the presence of limestone (causing some sticking in the bed). In test P-3B and P-3C it was decided the increase the differential pressure to compensate for the lower permeability. These 2 cycles were repeated in P-4A and P-4B where no flux was added. A higher ΔP was then used to improve firing penetration for a better particule bonding.

Test P-5A (0.1% 8C26) was run using the reference cycle P-1C.

Table VIII

Firing conditions

Zone	UDD	DDD	pH	F-1	F-2	F-3	F-4	F-5	F-6	F-7	Cooling	Total Time	Hearth Layer (cm)	Green bed (kg)	Green bed (cm)
Number of windboxes	7	3.5	2.5	2	2	2	2	2	2	5	16				
P-1B °C	230	260	760	1150	1290	1290	1290	1080	925	845	Amb.	39'35"	10.2	92	36
mm H_2O	510	510	510	510	510	510	510	510	510	510	560				
P-1C	Same T° as P-1B. ΔP decreased to 455 mm H_2O. GB bed height increased											39'35"	10.2	99	38
P-2A °C	250	260	760	1150	1290	1300	1300	1205	1040	870	Amb.	39'35"	10.2	99	38
mm H_2O	510	510	510	510	510	510	510	510	510	510	560				
P-2B	Same as P-1C											39'35"	10.2	99	38
P-3A	Same as P-2A											39'35"	10.2	99	38
P-3B	Same as P-2A with ΔP increased by 50 mm H_2O.											39'35"	10.2	99	38
P-3C	Same as P-1C with ΔP increased by 50 mm H_2O.											39'35"	10.2	99	38
P-4A	Same as P-3B											39'35"	10.2	99	38
P-4B	Same as P-3C											39'35"	10.2	99	38
P-5A	Same as P-1C											39'35"	10.2	99	40
P-6A °C	250	260	730	1065	1260	1330	1330	1290	1150	925	Amb.	41'34"	10.2	90	36
mm H_2O	510	510	510	510	510	510	510	510	510	510	560				
P-6B	Same as P-6A with GB bed decreased to 33 cm.											41'34"	10.2	84	33
P-7A	Same as P-1C											39'35"	10.2	99	40
P-8A	Same as P-2A											39'35"	10.2	99	39
P-9A	Same as P-3B											39'35"	10.2	99	38
P-9B	Same as P-3B with cycle duration increased to 42 min.											42'02"	10.2	99	38
P-10A	Same as P-9A (or P-3B)											39'35"	10.2	99	38
P-10B	Same as P-9B											42'02"	10.2	99	38
P-11A	Same as P-10A (or P-3B)											39'35"	10.2	99	38
P-11B	Same as P-10B (or P-9B)											42'02"	10.2	99	38

In test P-6A, we applied a firing profile adapted for fluxed pellets as recommended by IOCC. Some adjustments had to be made on the bed height in test P-6B to achieve a complete firing of the pellet bed.

Test P-7A (0.5% peat moss) was done with the cycle P-1C and test P-8A (0.075% 8C26 + 1.5% dolomite) with the "dolomite" cycle P-2A.

In tests P-5A, 7A and 8A no optimisation in the firing conditions were necessary since the firing of the pellet bed was well completed according to the temperature reached at the interface.

In the last 3 series of tests, the firing time had to be adjusted to account for the lower amount of Peridur or dolomite added. A more severe firing was then necessary to ensure a good particule bonding.

Table IX shows the air flow rates in all the steps of each firing test. One should note that the bed permeability was slightly lower when organic binders were used.

During the firing tests, the pellet temperatures at 4 different levels in the bed and in the outlet and inlet gas, as well as the pressure drop across the bed were recorded. The charts are shown in appendix 3. The original recording were sent to IOCC.

Table IX

Air flow rates ($Nm^3/m^2.min$)

Test #	UDD	DDD	P.H.	F-1	F-2	F-3	F-4	F-5	F-6	F-7	Cooling
P-1B	117	N/A	60	53	48	48	48	46	46	49	125
P-1C	112	N/A	71	56	44	44	44	39	39	41	113
P-2A	103	N/A	66	51	44	35	35	32	32	37	107
P-2B	106	N/A	64	49	37	37	37	30	31	33	95
P-3A	103	N/A	62	46	44	34	34	30	30	35	101
P-3B	108	N/A	68	49	42	39	39	39	39	45	110
P-3C	108	N/A	64	48	35	35	35	30	30	35	106
P-4A	109	N/A	69	51	42	37	37	37	37	40	113
P-4B	115	N/A	69	49	39	39	39	35	35	38	113
P-5A	102	N/A	58	44	35	35	35	27	27	30	100
P-6A	108	N/A	70	53	38	35	35	32	32	38	122
P-6B	110	N/A	71	60	40	34	34	32	33	38	126
P-7A	119	N/A	70	49	40	40	40	35	37	39	114
P-8A	115	N/A	73	55	47	39	39	39	39	43	125
P-9A	104	N/A	66	48	42	34	34	32	35	39	115
P-9B	108	N/A	69	56	39	34	34	33	35	38	119
P-10A	104	N/A	64	44	43	33	33	32	32	36	110
P-10B	109	N/A	69	48	36	34	34	32	32	38	118
P-11A	108	N/A	66	44	39	33	33	30	30	32	114
P-11B	105	N/A	68	47	33	32	32	32	32	37	116

These curves were analysed and the important data reported in table X. The time at which the pellets were exposed to a T° higher than 1205°C (T° considered as a minimum to attain a reasonable pellet strength) is an indication of the firing intensity. The firing of the bed is considered to be completed when the interface green ball - hearth layer has reached that T° for at least 1 minute. Tests #P-3A and P-3C were slightly underfired.

The maximum T° reached in the lower layers are also reported. The T° of the outlet gas corresponds to the "burnt through T°" and is the T° reached at the last windbox of the firing zone (Windbox #30).

5.2.3 Fired pellet properties

The cheminal analysis of the fired pellets are shown in table XI. The pellets from test #P-5A were not analysed because of their poor quality. All the samples showed a low FeO content which indicates that the magnetite was completely oxydized.

Table XII summarizes the fired pellet physical properties. A tumble index of less than 4.0% (-0.5 mm) and a compressive strength of more than 250 kg are considered typical of good quality pellets.

Table X

Analysis of bed and gas T° curves

Test #	Time at T° >1205°C (min)			Maximum T° reached (°C)		
	Top	Center	Interface	Interface	Hearth Layer	Outlet Gas*
P-1B	11.7	12.0	5.5	> 1315	1270	N/A
P-1C	12.9	12.9	3.3	> 1315	1205	N/A
P-2A	14.4	11.2	1.6	1265	1055	N/A
P-2B	13.2	11.0	1.2	1255	925	N/A
P-3A	14.3	9.7	0.1	1210	775	N/A
P-3B	11.3	11.3	2.5	1290	1080	N/A
P-3C	9.9	11.4	0.9	1245	970,	N/A
P-4A	14.5	11.9	2.9	1315	1140	N/A
P-4B	11.9	10.0	3.1	> 1315	1165	N/A
P-5A	15.6	10.3	1.9	1280	925	530
P-6A	14.0	10.7	2.5	1245	1140	765
P-6B	12.5	10.8	4.3	1265	1195	825
P-7A	16.6	12.4	4.7	1315	1115	680
P-8A	17.7	10.7	3.5	1310	1220	820
P-9A	16.4	11.3	0.7	1225	1010	555
P-9B	17.3	12.0	2.9	1275	1140	710
P-10A	17.5	10.6	0.2	1210	940	565
P-10B	19.3	13.7	2.2	1265	1080	720
P-11A	18.5	8.9	0.3	1215	920	570
P-11B	16.4	11.7	3.0	1290	1085	675

Table XI

Chemical analysis of fired pellets

Test #	Fe	FeO	SiO_2	Al_2O_3	CaO	MgO	S
P-1B	65.7	<0.01	4.88	0.25	0.73	0.36	<0,01
P-1C	-	<0.01	-	-	-	-	<0,01
P-2A	65.2	0.16	4.28	0.17	0.97	0.63	<0,01
P-2B	-	0.10	-	-	-	-	<0,01
P-3B	65.0	<0.01	4.94	0.13	1.08	0.33	<0,01
P-3C	-	<0.01	-	-	-	-	<0,01
P-4A	65.6	<0.01	4.92	0.13	0.56	0.30	<0,01
P-4B	-	<0.01	-	-	-	-	<0,01
P-6A	61.5	<0.01	4.34	0.17	4.34	1.82	<0,01
P-7A	65.7	<0.01	4.86	0.17	0.56	0.33	<0,01
P-8A	65.7	<0.01	4.73	0.15	0.84	0.58	<0,01
P-9A	64.7	0.17	4.62	0.21	1.06	0.68	<0,01
P-9B	-	0.09	-	-	-	-	<0,01
P-10A	-	0.04	-	-	-	-	<0,01
P-10B	64.7	0.03	5.22	0.15	0.83	0.61	<0,01
P-11A	-	0.04	-	-	-	-	<0,01
P-11B	65.2	0.02	5.56	0.17	0.78	0.53	<0,01

Table XII

Fired pellets physical properties

Test #	Tumble ASTM (%)		Compressive strength (kg)							Open pores	Satmagan
	+6,3 mm	-0,5 mm	Top	Center	Bottom	$\bar{x}$	σ_{n-1}	%-140kg	%-90kg	(%)	(%)
P-1B	96.9	3.0	315	384	336	345	71	0	0	24.9	1.8
P-1C	96.6	3.3	335	387	370	364	86	0	0	24.6	1.7
P-2A	96.1	3.8	287	300	338	309	75	2	0	26.7	1.3
P-2B	95.7	4.2	333	344	324	334	59	0	0	26.7	1.2
P-3A	93.2	6.7	390	326	306	341	89	0	0	-	N/A
P-3B	96.6	3.3	353	365	325	347	71	0	0	27.5	0.8
P-3C	94.9	5.0	332	354	339	342	84	0	0	27.6	0.9
P-4A	96.3	3.6	321	343	306	323	71	0	0	25.5	0.9
P-4B	95.6	4.3	317	321	275	304	71	2	2	25.6	1.0
P-5A	93.3	6.6	279	260	256	265	63	0	0	31.1	N/A
P-6A	96.1	3.8	339	303	235	293	70	2	0	29.5	5.4
P-6B	95.7	4.3	304	318	269	297	55	0	0	29.0	N/A
P-7A	93.5	6.4	206	254	218	226	58	3	2	29.3	0.8
P-8A	95.0	4.9	315	316	292	307	63	0	0	28.9	1.2
P-9A	95.6	4.3	336	330	273	313	63	0	0	27.1	1.0
P-9B	96.3	3.6	373	363	322	353	65	0	0	26.9	1.0
P-10A	95.6	4.4	354	331	303	329	65	0	0	28.1	1.2
P-10B	96.6	3.3	354	343	333	343	65	0	0	26.8	1.1
P-11A	96.0	3.9	337	348	259	315	65	0	0	27.2	1.1
P-11B	96.2	3.7	326	322	312	320	60	0	0	26.7	1.1

The results obtained with Peridur C-10 were excellent even when no fluxes were added (test #P-4A). As expected a 1.0% addition of limestone (test #P-3B) resulted in a higher compressive strength.

The production of fluxed pellets using the Peridur C-10 also showed some good results. The tumble index and compressive strength were slightly deteriorated as it is expected for that type of pellets.

The firing strategy applied in test #P-2A (with higher firing T° as compare to P-1C) gave the best results with Periduc C-10 for acid pellets with or without a small addition of dolomite or limestone.

The pellets from test #P-5A (with 0.1% 8C26) did not meet the specifications for the tumble index. This can be attributed to the low dry ball strength and to the pellet surface which was weakly bonded. The pellet porosity was very high due to the high moisture level in the green balls.

In test #P-8A it was decided to lower the 8C26 addition rate to 0.075% to reduce the green ball % H_2O and to add 1.5% dolomite to promote bondind of the fired pellets. This resulted in better strength but the tumble index was still out of specifications.

The test #P-7A, with peat moss, did not result in acceptable pellet quality.

In test P-9B it is shown that some excellent results can be obtained with an addition rate of 0.075% Peridur C-10 and 1.5% dolomite. However it was necessary to increase the firing cycle time by aout 6% as compared to test P-2A where 0.10% Peridur was added.

The tests P-10A and P-11A can be compared to P-2A and P-4A. In these 4 tests the Peridur rate was kept at 0.1% while the dolomite addition was varied from 0 to 1.5%. No significant effect was observed on the pellet physical strength.

In tests P-10B and P-11B, it is shown that the physical properties of Peridur pellets can be further improved by increasing the firing time.

All the values obtained with the Satmagan are typical of industrial results. The higher number in test #P-6A is due to the formation of magnesio-ferrite promoted by the high amount of MgO in the mix.

Table XIII shows the results of the metallurgical tests done on selected pellet samples.

The reducibility indices of acid pellets made with Peridur C-10 are clearly above that of the reference bentonite pellet (P-1C). A comparison of test P-1C with P-4A and 4B (in which no dolomite or limestone were added) shows an increase of about 0.15 $\%O_2$/min. This is partly due to the higher pellet porosity in the tests with the organic binder. The value of 1.37% O_2/min obtained in test P-6A (fluxed pellets) is also remarkable. The addition of up to 1.5% dolomite did not have any significant effect on the reducibility.

Table XIII

Fired pellets reducibility, swelling and LTD

Test #	R_{40} ISO	Free Swelling ISO		LTD ISO (2% H_2)		
	(%O_2/min)	% Vol.	°Red.	+6,3 mm	+3,15 mm	-0,5 mm
P-1C	0.56	17.7	38.3	94.0	95.7	4.1
P-2A	0.76	21.1	44.7	92.9	93.8	6.1
P-2B	0.78	-	-	-	-	-
P-3B	0.74	22.3	41.5	95.9	96.3	3.5
P-3C	0.81	-	-	-	-	-
P-4A	0.70	26.1	44.3	95.4	95.9	4.0
P-4B	0.73	-	-	-	-	-
P-6A	1.37	18.0	57.9	95.2	95.7	4.2
				*(95.4	95.8	4.1)
P-6B	1,10	-	-	-	-	-
P-9A	0.81	-	-	-	-	-
P-9B	0.69	21.3	43.6	89.9	92.8	6.7
P-10A	0.74	-	-	-	-	-
P-10B	0.68	22.3	43.8	91.7	94.4	5.4
P-11A	0.69	-	-	-	-	-
P-11B	0.73	21.5	42.8	93.6	94.9	4.8

* Recheck

The swelling indices of Peridur pellets were much higher than that of bentonite (26,1% Vs 17.7%).

The high swelling of Peridur pellets was decreased to an acceptable level by a small addition of dolomite or limestone. The fluxed pellets made with Peridur had a fair swelling index.

The higher swelling of Peridur acid pellets could be explained by the fact that less impurities disburb the alignment of the grains during the recrystallization. More research work would be necessary to verify this hypothesis.

The results of the Low Temperature Desintegration (LTD) tests were very good for all the samples. In the case of the fluxed pellets P-6A, the LTD is considered to be excellent. The LTD results were slightly deteriorated by a small addition of dolomite (up to 1.5%) but still remained within the acceptable limits.

Some further testwork is recommended to optimize the pellet physical and metallurgical properties. This work could include the effect of lower and higher Peridur C-10 addition rates on acid and fluxed pellet quality.

Table XIV summarizes the results of some softening temperature tests done on selected samples. The values obtained from bentonite and Peridur acid pellets are comparable. The addition of a small amount of dolomite does not significantly affect the results. The values obtained for the test P-6A are typical of good fluxed pellet quality.

Table XIV

Fired pellets softening Temperature (°C)

Test #	$T_{10}\%$(1)	$T_{20}\%$	$T_{30}\%$	$T_{40}\%$	$T_{50}\%$	$T_{55}\%$	$T_{60}\%$	FDR(2)
P-1C	1076	1119	1139	1157	1177	1194	1215	55.3
P-2A	1060	1097	1120	1144	1165	1180	1207	58.3
P-3B	1068	1099	1120	1135	1153	1166	1183	55.1
P-4A	1073	1110	1130	1154	1168	1178	1190	57.6
P-6A	1090	1147	1179	1213	1251	1272	1303	71.2
P-9B	1059	1100	1124	1143	1158	1170	1185	52.1
P-10B	1052	1095	1120	1139	1163	1170	1190	56.1
P-11B	1065	1112	1135	1155	1174	1185	1200	58.1

(1) T° at 10% contraction.
(2) Final degree of reduction.

6. COLLABORATION

The author appreciates the collaboration of Mr. Jean-Louis Blais, senior technician, and Mr. André Blais who have done the laboratory and pilot scale tests. We should also mention the support of the clerical staff for the typing of this report.

Appendix 1

Calorific values of wet and dry
peat moss

Services de Surveillance SGS Inc.
SGS Supervision Services Inc.
Redwood Petroleum and Petrochemical Division
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Montréal-East, Québec., Canada, H1B 5B4
Téléphone: (514) 645-8754 - Télex: 05829680

RAPPORT D'ANALYSE

A : GOUVERNEMENT DU QUEBEC
Ministere de l'energie et des Ressources
Usine Pilote
1188 Place Dufresne
Quebec, Quebec, G1N 1X7
Attn: M. Guy Paquet

DATE: 29 Janvier 1988

NO.:
DOSSIER: 88,6189

Analyse de deux (2) echantillons de Tourbe recus le 25 janvier 1988.

RESULTATS

ECHANTILLON	BTU/LB
Echantillon Tourbe seche compose des Barils 1 et 2 (2616)	7451
Echantillon Tourbe humide % H20 = 88 %	1818

Elvio Abbruzzese
Chimiste

EA/lj

MEMBER OF THE SGS GROUP (Société Générale de Surveillance)
TOUTES NOS INSPECTIONS SONT EFFECTUÉES DE BONNE FOI AU MEILLEUR DE NOS CONNAISSANCES ET NOTRE RESPONSABILITÉ SE LIMITE À L'EXERCICE DE NOS FONCTIONS AVEC TOUS LES SOINS REQUIS.
ALL INSPECTIONS ARE CARRIED OUT TO THE BEST OF OUR KNOWLEDGE AND ABILITY AND OUR RESPONSIBILITY IS LIMITED TO THE EXERCISE OF REASONABLE CARE.

Appendix 2

Calculation of flux addition in test #B-6

Test #B-6

	SiO_2	CaO	MgO	PAF	Total
Filter cake (1000 kg)	48.00	4.50	3.00	10.00	990.00
Dolomite (7.5%= 75 kg)	2.25	22.50	15.75	33.75	41.25
Limestone (3.5%= 35 kg	1.05	19.25	0.70	14.00	19.00
	51.30	46.25	19.45	57.75	1050.25
	4.88	4.40	1.85	5.50	

CaO/SiO_2 = 0.90 MgO= 1.85%

Appendix 3

Firing temperature curves

* T° scale linear from 0 to 2500°F

01 : Hearth layer (1" above the grate)

02 : Bottom of the bed (½" above interface)

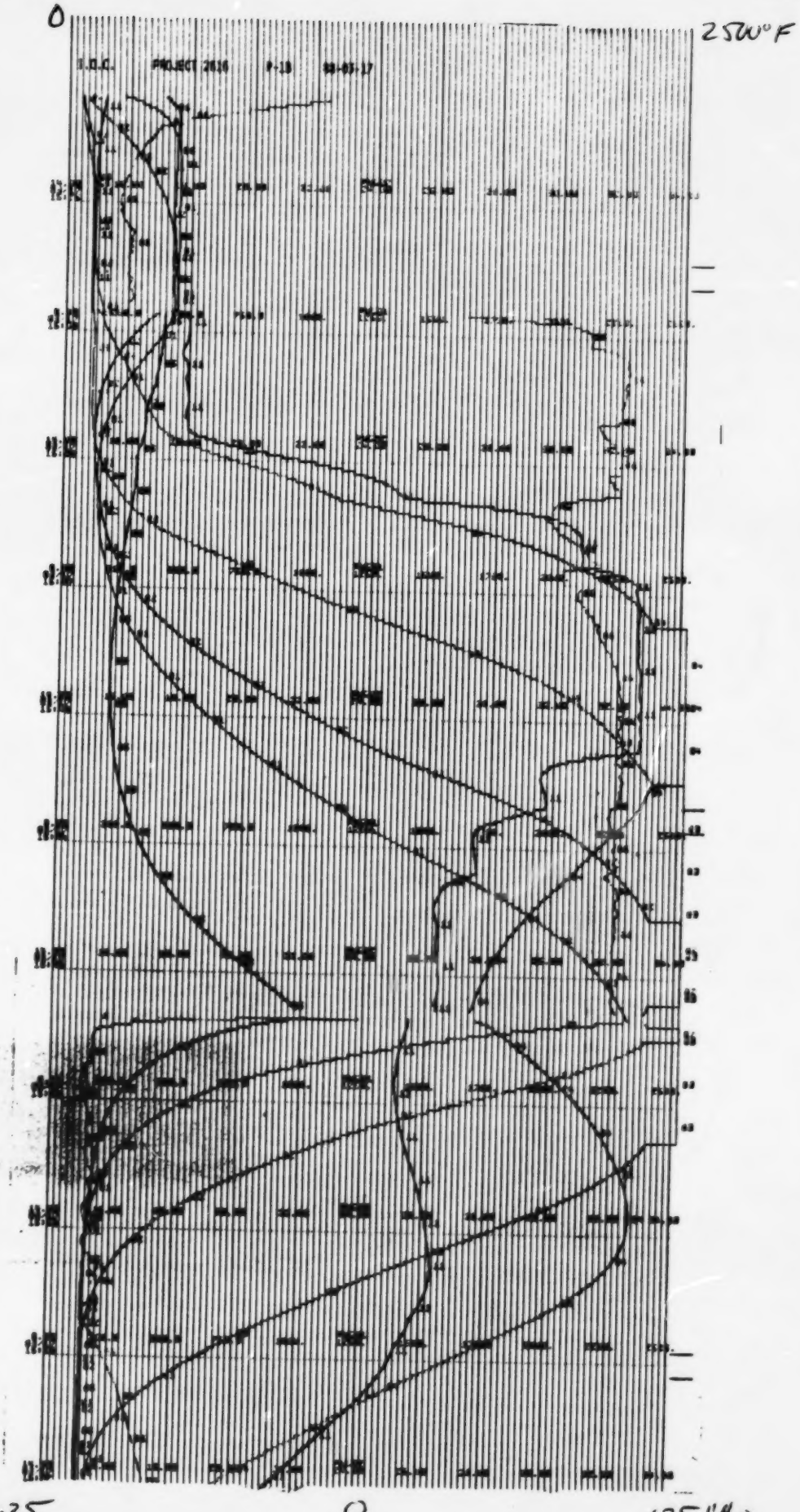
03 : Center of the green bed

04 : Top of the bed (1" in the bed)

05 : Gas T° under the bed (inlet gas for UDD and cooling zones and oulet gas for the others)

11 : Gas T° above the bed (outlet gas for UDD and cooling zones and inlet gas for the others)

06 : Pressure drop across the bed (linear scale from -25 to + 25" H_2O)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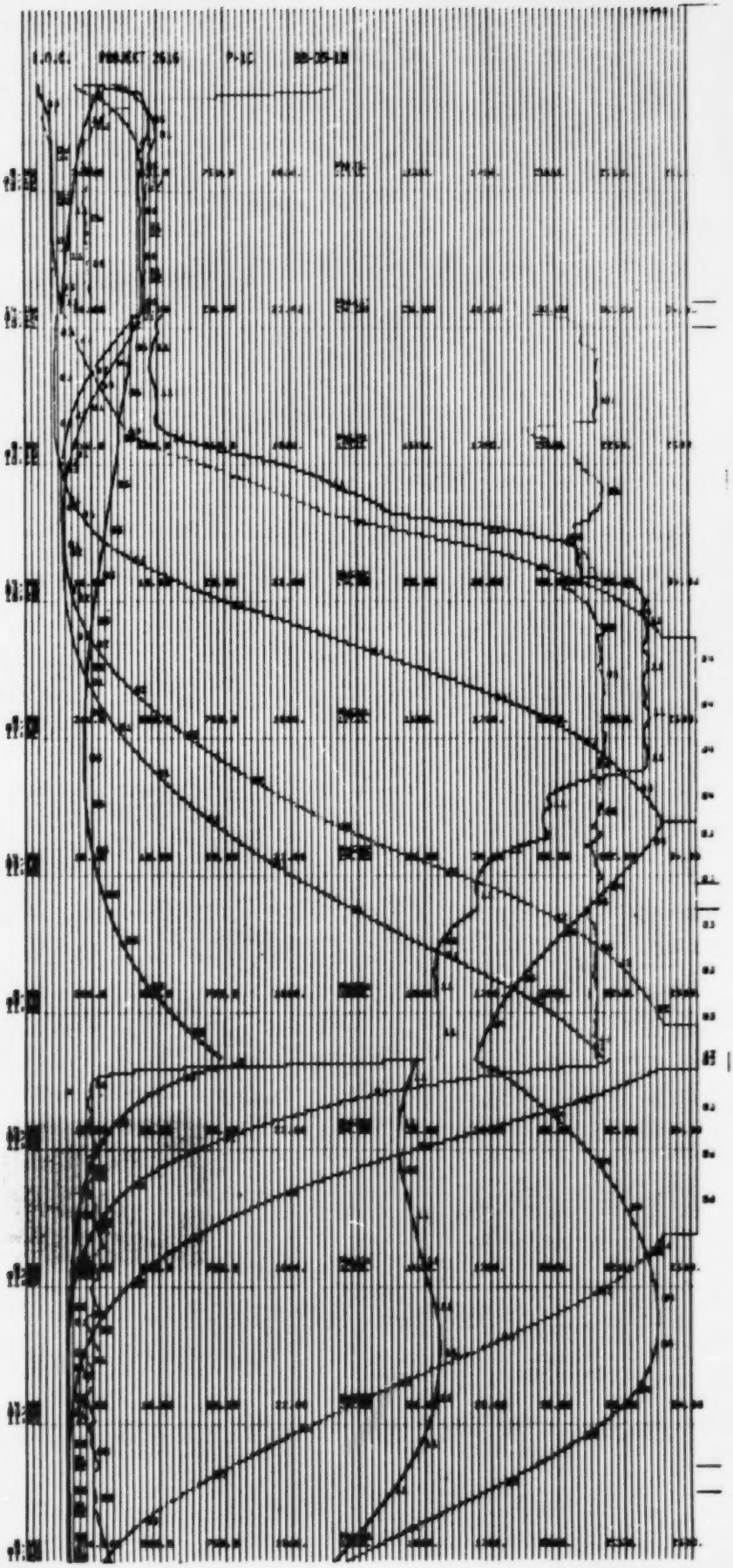
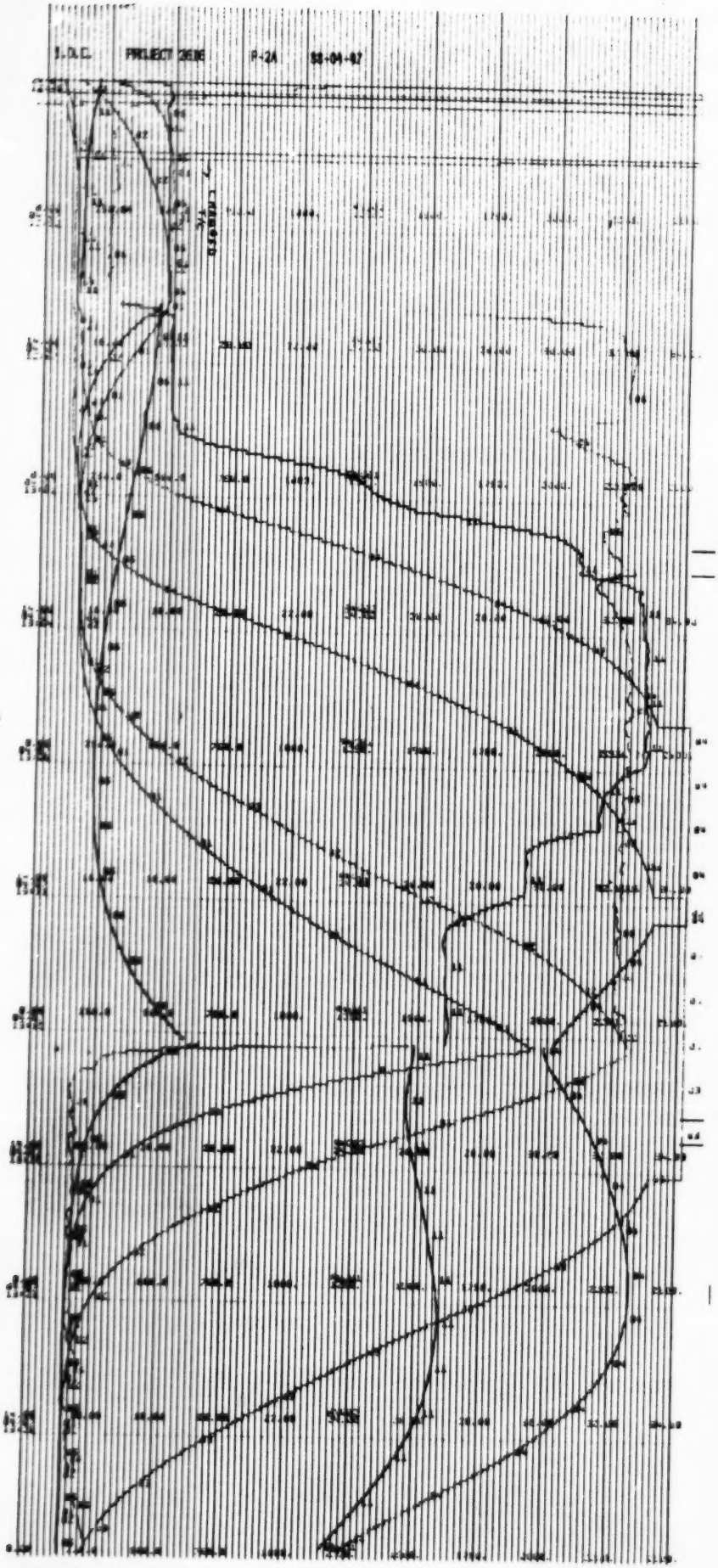
0
+25 "H2O

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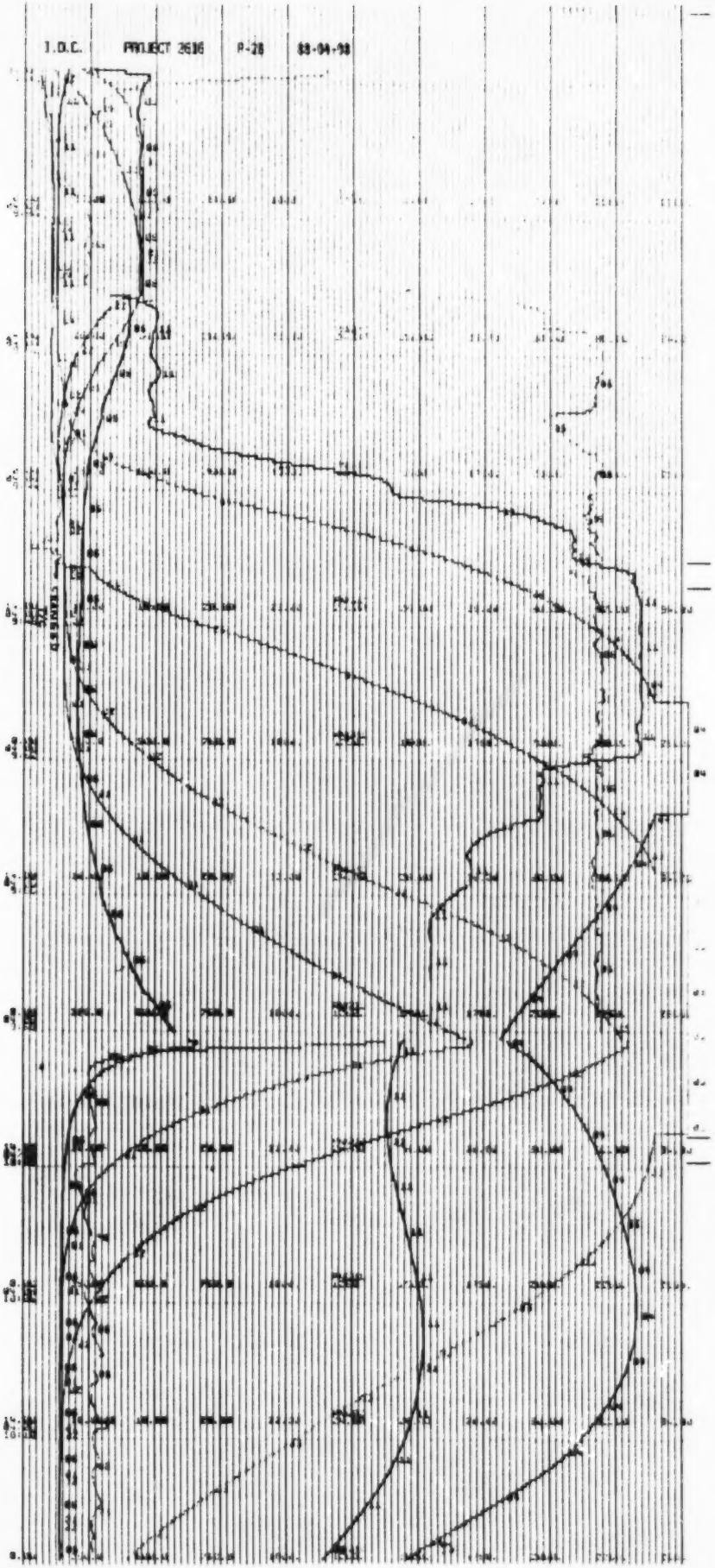
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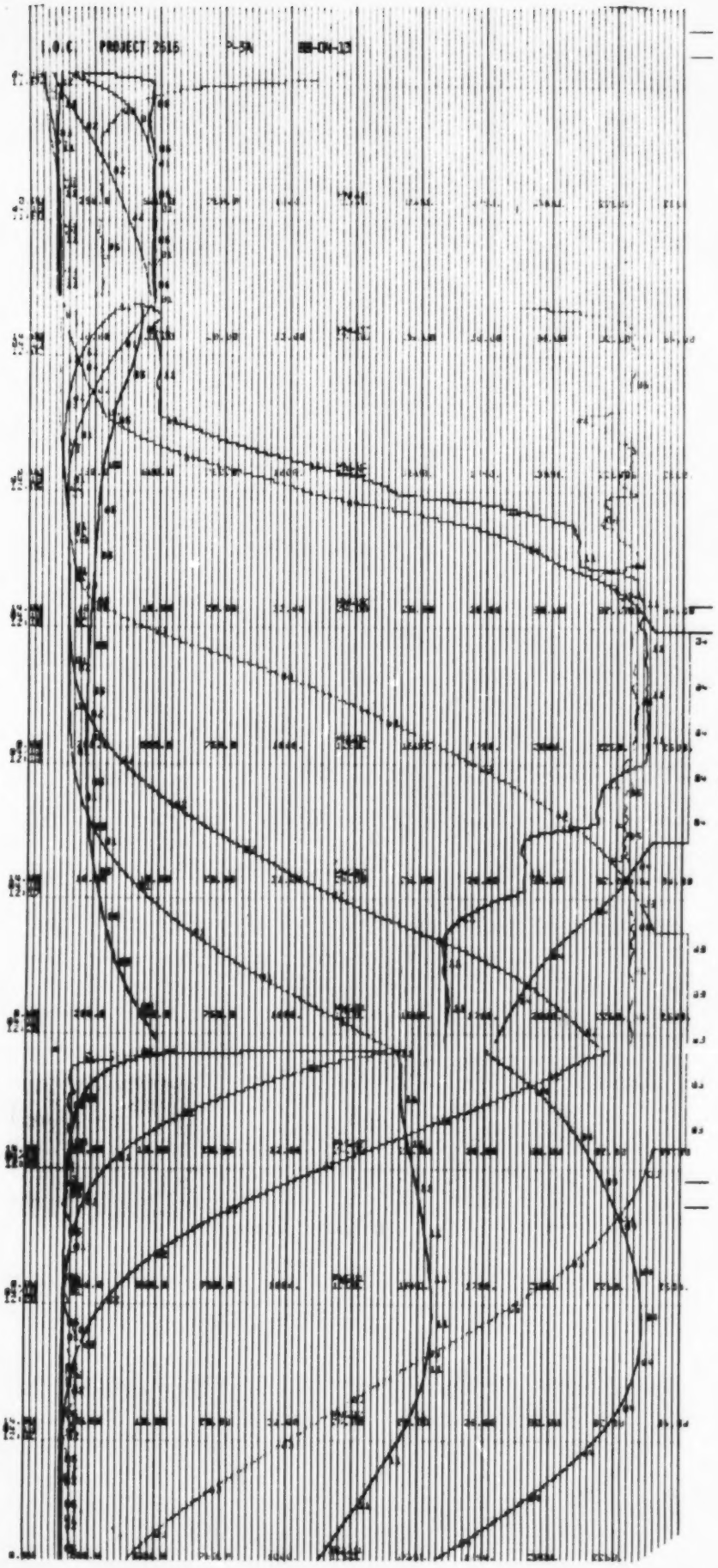
P-28
88-04-08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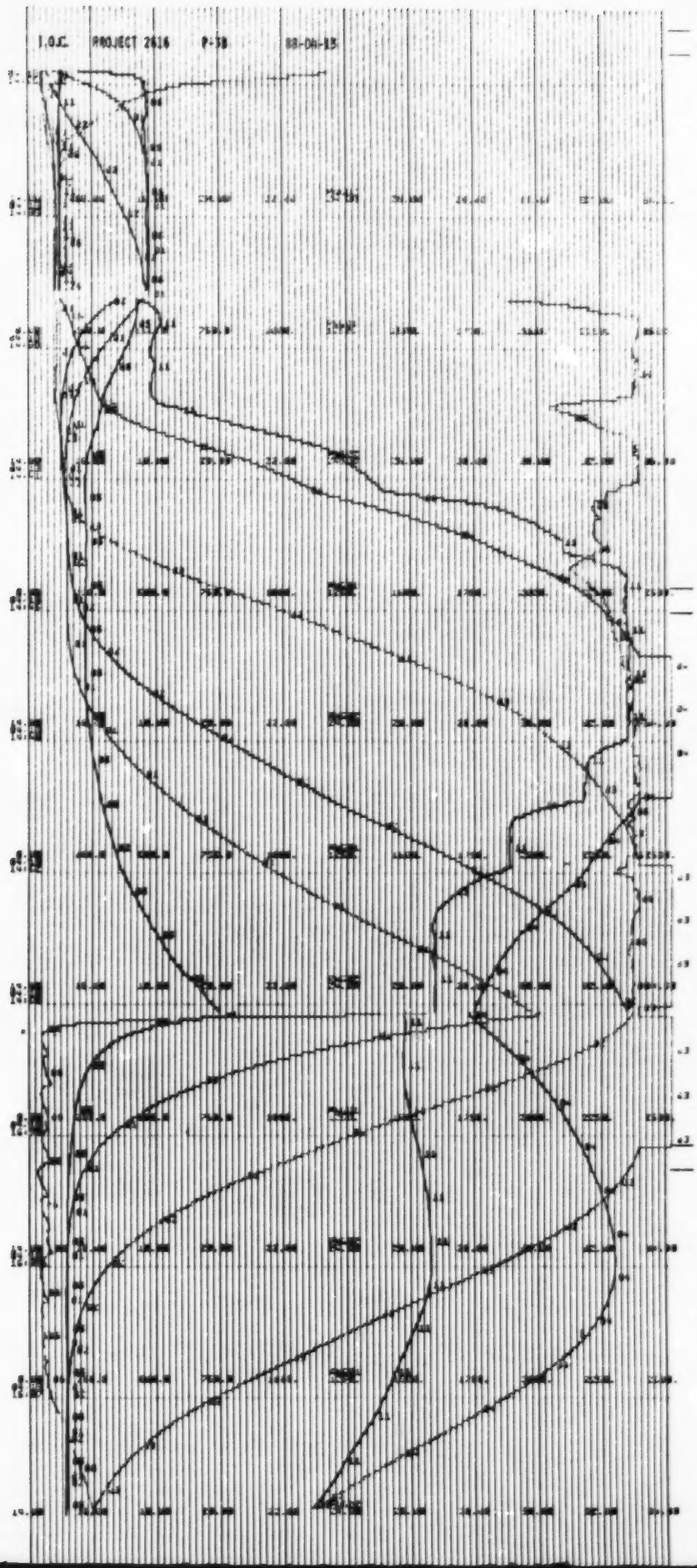
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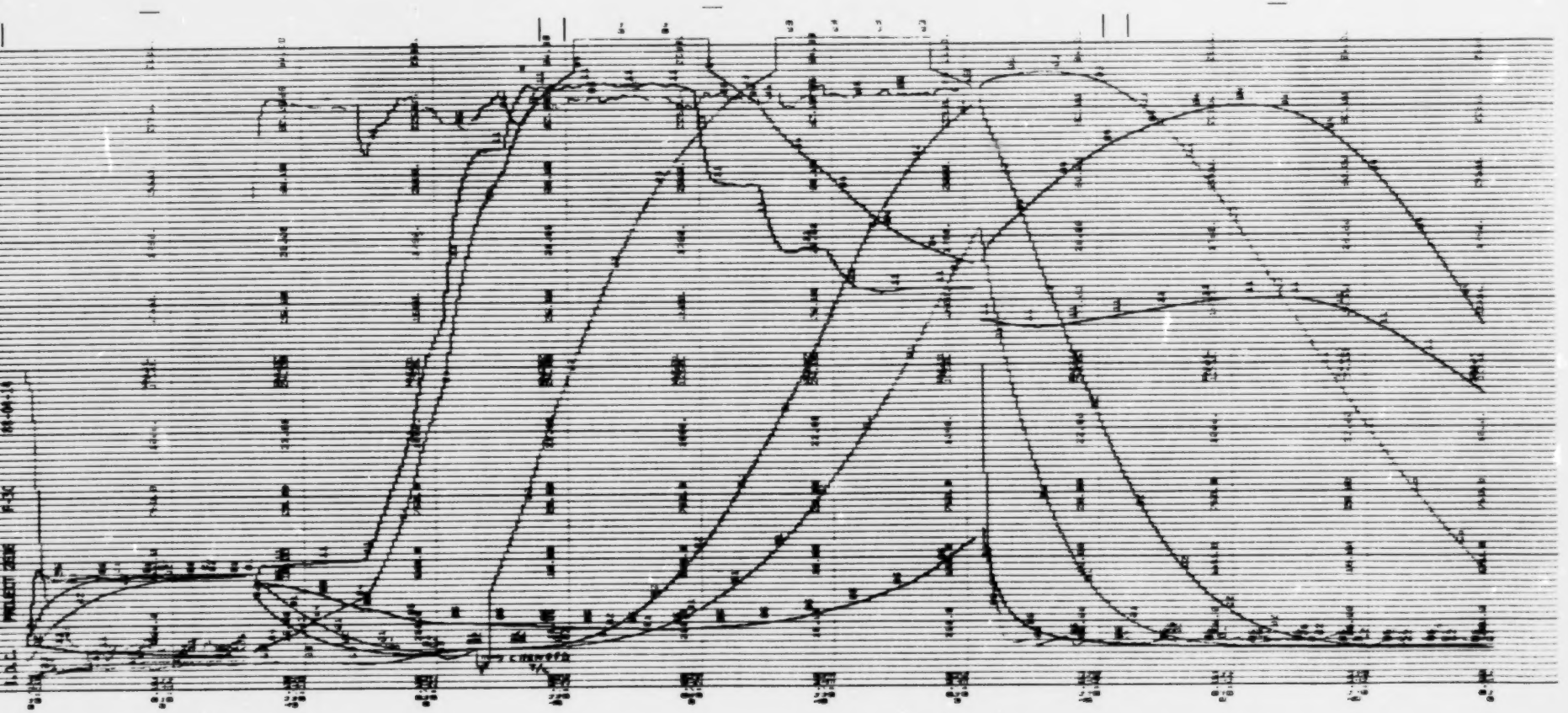

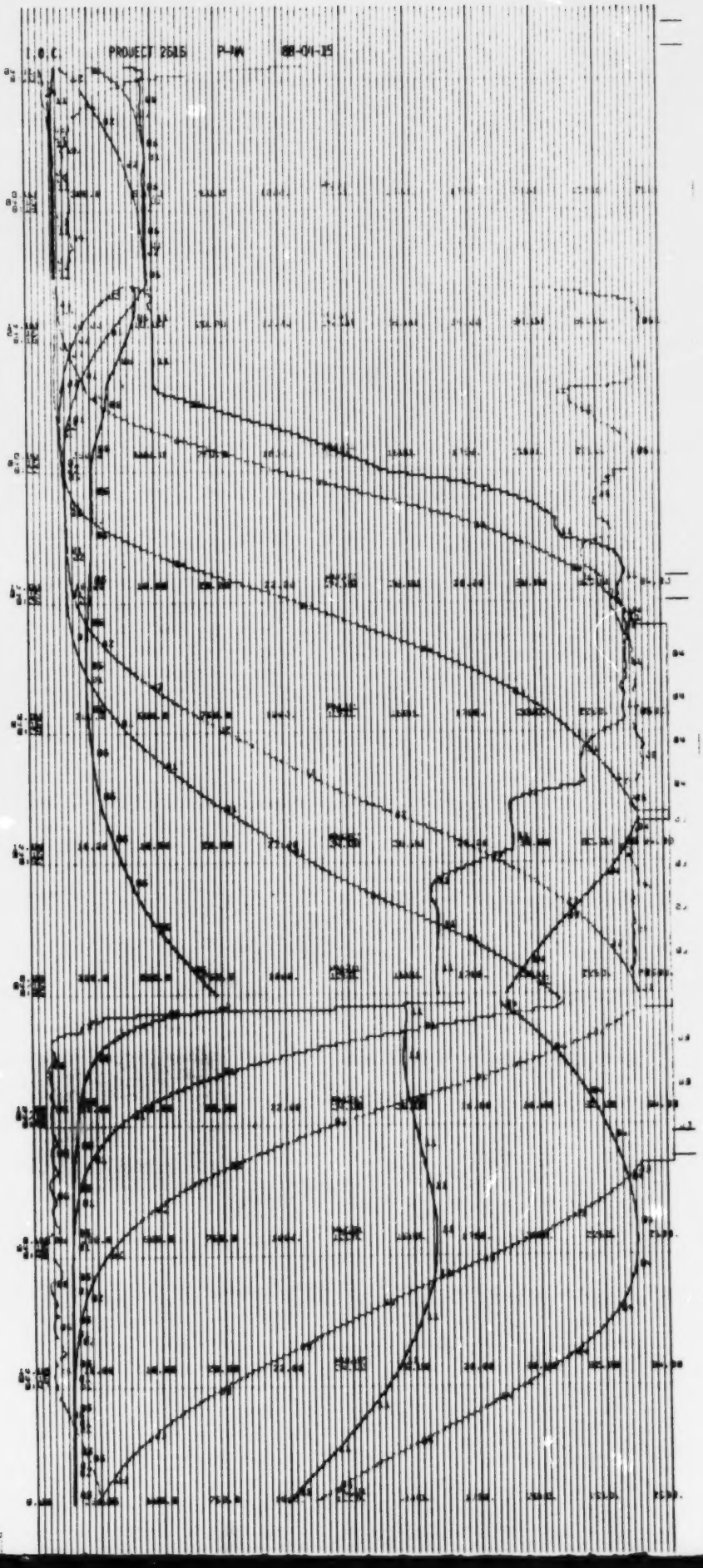
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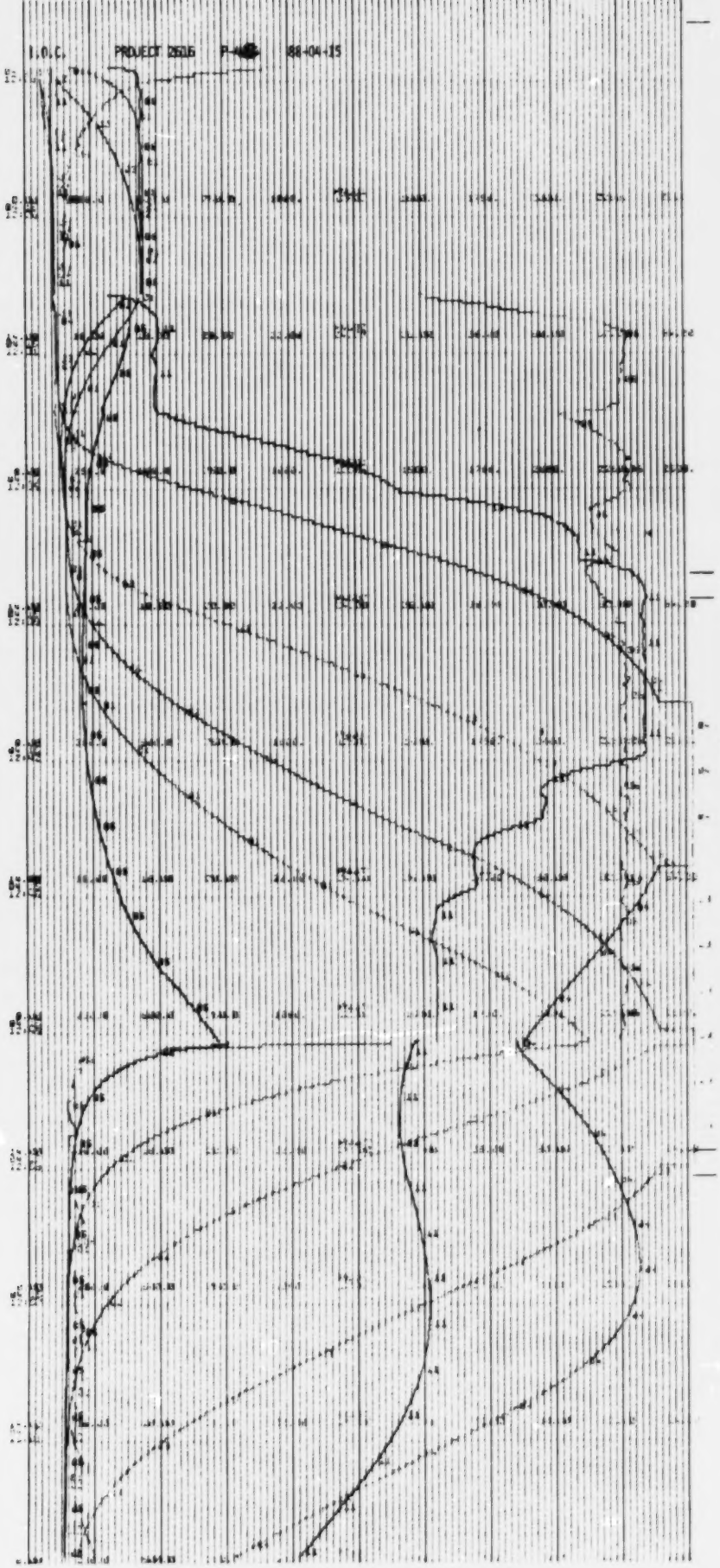
P-4W
88-04-25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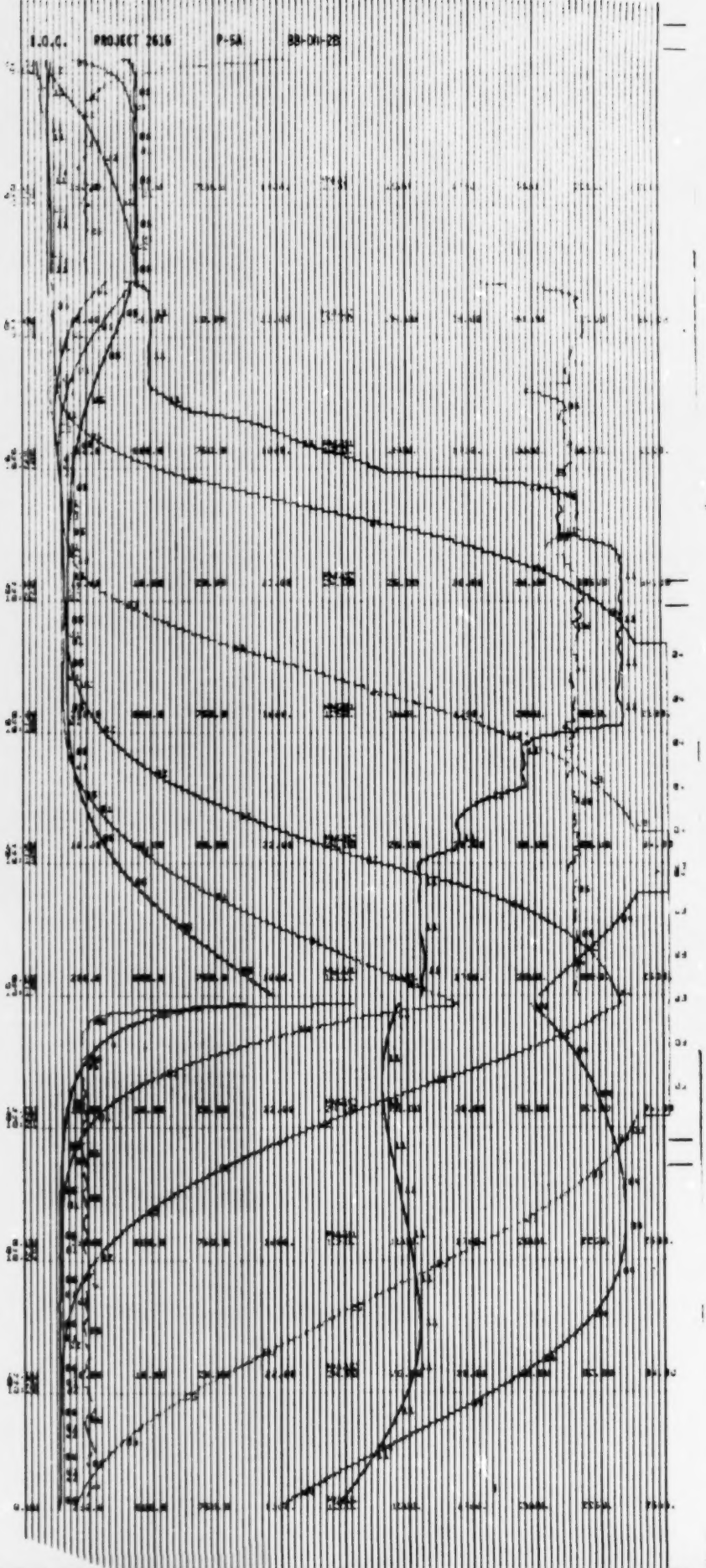
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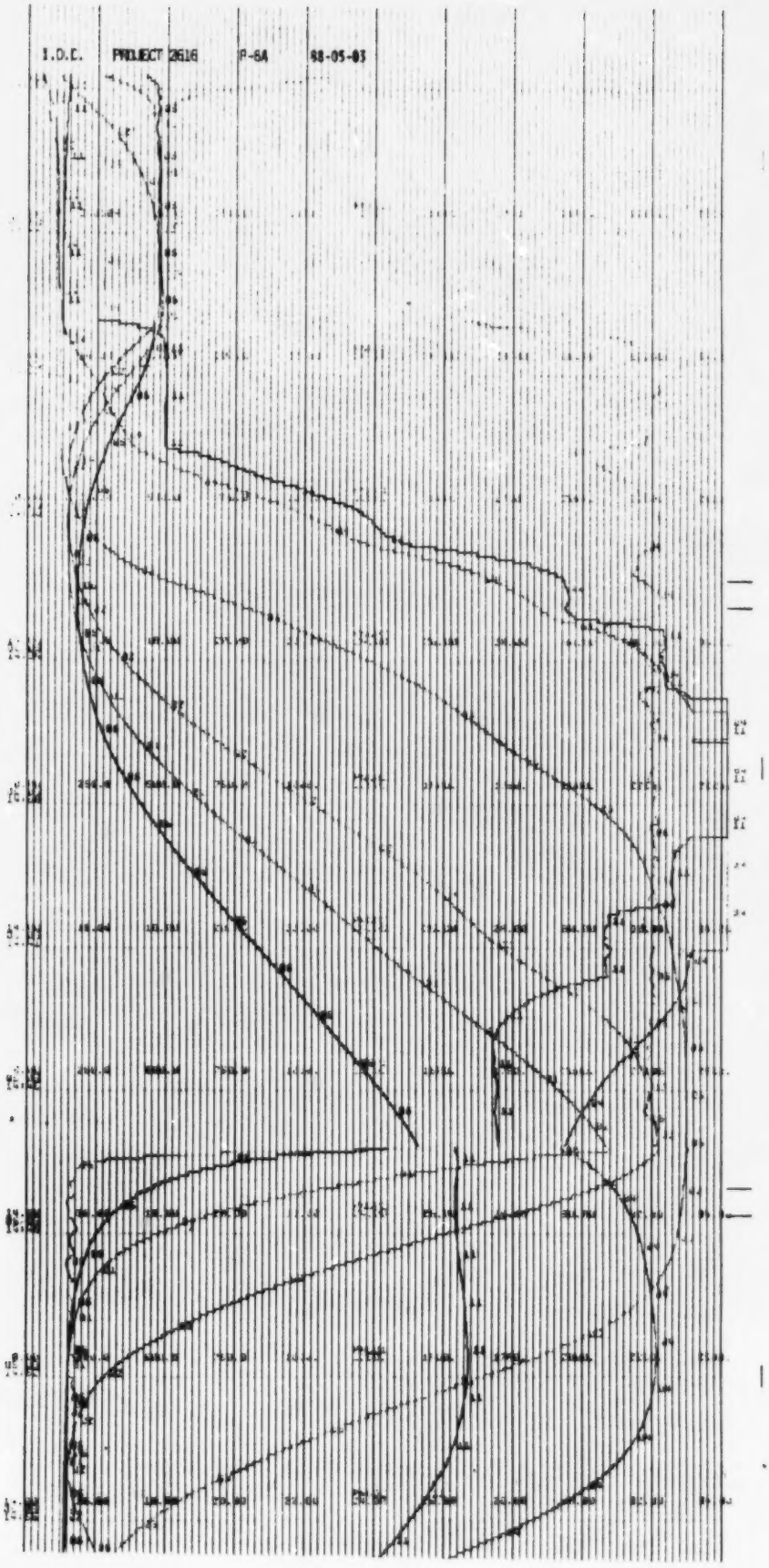
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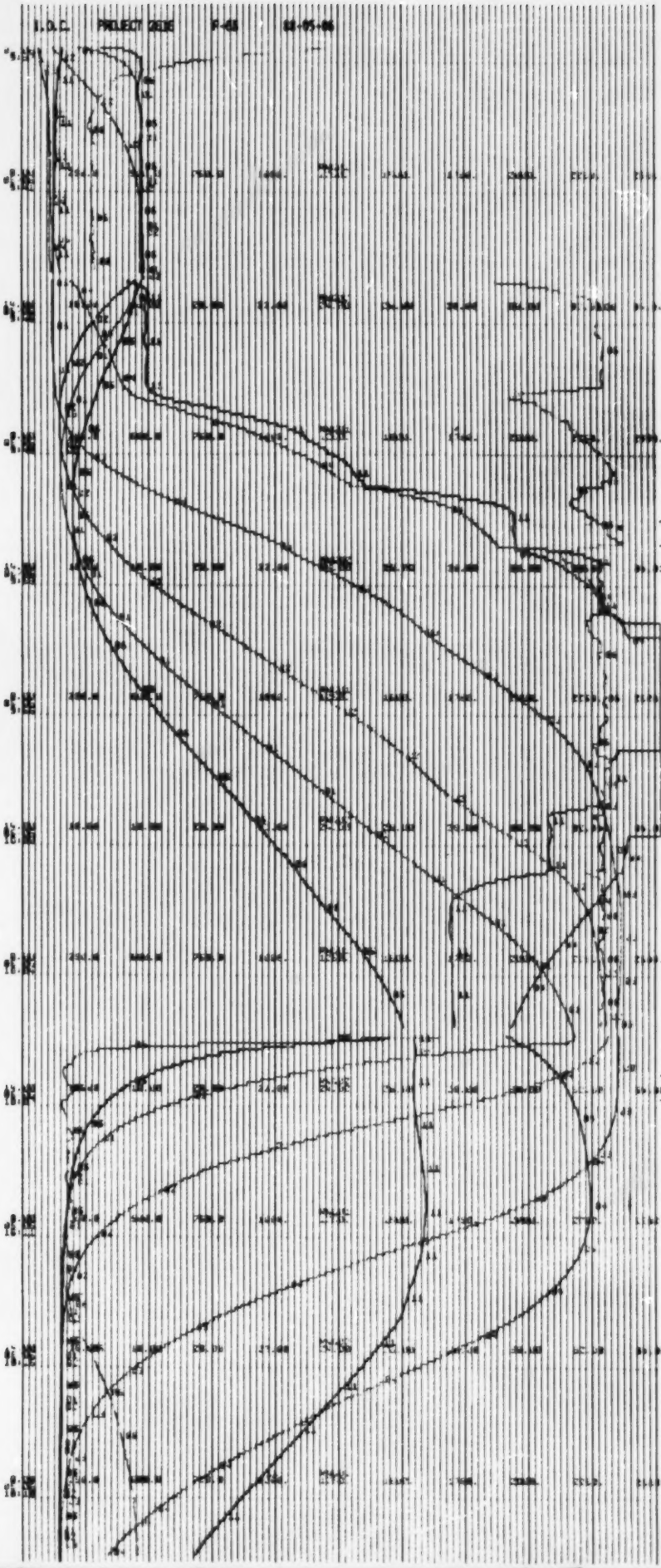
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